Multi-Scale Analysis of the Spatio-Temporal Complementarity of Solar and Wind Resources in West Africa: The Case of Guinea

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CONTEXT AND PROBLEMATIC

In light of the challenges posed by climate change and the current energy supply situation, the Intergovernmental Panel on Climate Change (IPCC) has identified the global energy transition as a priority. However, despite the abundance of renewable energy sources, particularly solar and wind power, in many regions of the world and especially in West Africa, these sources are heavily influenced by the day-night cycle and weather conditions, making them intermittent. This variability leads to imbalances between energy production and demand, often requiring the integration of storage systems to ensure a continuous supply. However, energy storage, which is mainly based on electrochemical batteries, remains a technically and economically challenging solution.

It is against this backdrop that this article aims to propose an approach to optimising renewable energy production based on exploiting the interplay between different sources, thereby reducing the need for energy storage. This approach is particularly important for reducing the cost of implementing such systems, improving their sustainability, and thus encouraging the integration of renewable energy into countries' energy mixes.

This study employs statistical models, notably Pearson's correlation coefficient and the compensation ratio, to identify areas likely to offer spatio-temporal complementarities for energy compensation. Subsequently, a storage ratio index is proposed to quantify the reduction in storage capacity required by the compensation system, compared with a single-source configuration or positively correlated sources

Applied to Guinea's eight administrative regions using satellite data extracted from NASA's POWER database, our analysis shows that, in all regions, solar radiation is inversely correlated with wind speeds measured in Conakry. This indicates a potential for these resources to complement one another in these regions. However, it remains insufficient at all levels of analysis to make a project viable without further measures.

METHODOLOGY AND MATERIALS

Hybrid renewable energy systems are energy infrastructures that combine two or more renewable energy sources. They make it possible to increase instantaneous generation capacity or to mitigate the impact of intermittency. Where generation capacities are combined, the impact of intermittency is entirely offset by the storage systems provided for this purpose. The other approach, which helps to reduce the impact of intermittency, involves exploiting the spatial and temporal complementarity that these sources can offer

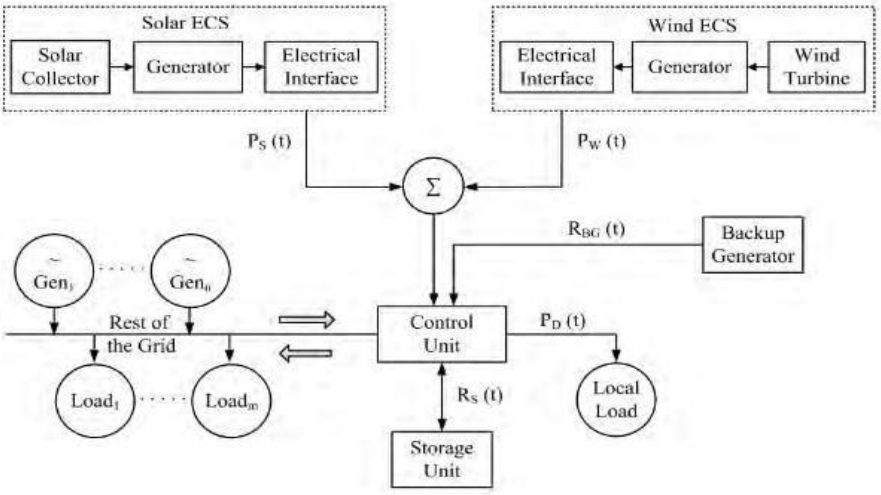

Figure 1:Architecture d'un système hybride

Complementarity refers to a method of optimising the use of renewable energy sources that helps to mitigate the effects of their intermittency. It can be temporal, within a single site, or spatiotemporal, across multiple sites. In this study, we used Pearson's correlation coefficient to analyse the spatiotemporal variation of the sources. This coefficient takes values between -1 and 1. To be considered significant for compensation, it must lie between -0.4 and -1, which implies an alternating pattern

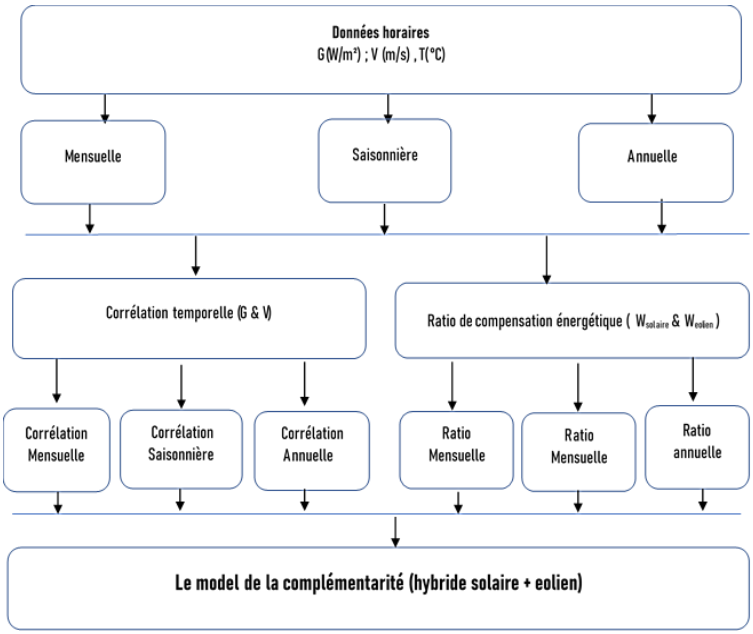

Figure 2 : Démarche méthodologique

RESULTS AND DISCUSSIONS

Figure 3 shows the results of the analysis of the spatiotemporal correlation between solar and wind resources for eight(8) regions of Guinea Conakry on an annual basis.

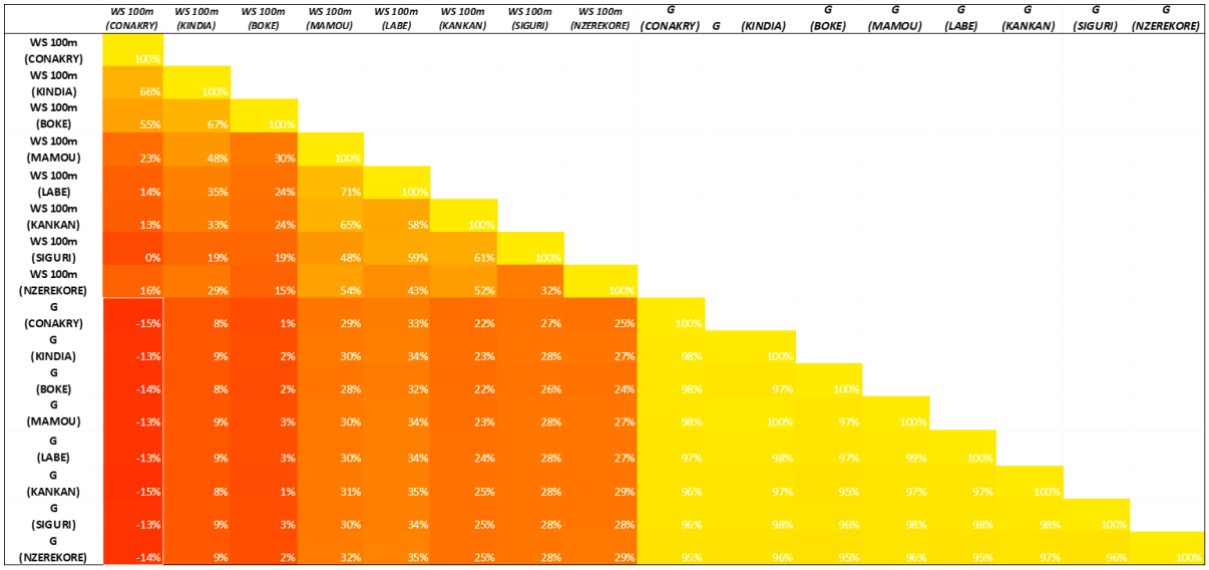

Figure 3 : résultats de l'analyse de la corrélation spatiotemporel

From this figure showing the correlation matrix, we can see that the correlation between the sources is positive for most regions. This indicates that they vary in the same direction and that no offsetting is possible in this case. However, we can see that Conakry's wind resource is inversely correlated with the solar resource of the other regions, even though this correlation remains weak on an annual scale. Nevertheless, if it proves significant on a seasonal scale, this could be useful for mitigating the seasonal intermittency of the sources

The table below presents the results of the seasonal analysis of the temporal correlation for regions with a negative annual correlation. The table below shows that the seasonal analysis reveals generally weak correlation results. This might lead us to conclude that the potential for complementarity between solar and wind power is low. It is even lower during the dry season than during the rainy season.

Tableau 1 : *Corrélation saisonnière*

Regions	Corr. annulelle	appreciation	Corr. Saison seche	appreciation	Corr. Saison pluvieuse	appreciation
WSP-G-(conakry)	-0.15	faible	-0.14	faible	-0.14	faible
WSP-G- (conakry-kindia))	-0.13	faible	-0.14	faible	-0.10	faible
WSP-G (conakry-BOKE)	-0.14	faible	-0.12	faible	-0.14	faible
WSP-G (CONAKRY-MAMOU)	-0.13	faible	-0.14	faible	-0.10	faible
WSP-G (CONAKRY-LABE)	-0.13	faible	-0.14	faible	-0.09	faible
WSP-G (CONAKRY-KANKAN)	-0.15	faible	-0.18	faible	-0.11	faible
WSP-G (CONAKRY-SIGUIRI)	-0.13	faible	-0.16	faible	-0.09	faible
WSP-G (CONAKRY-NZERZKO)	-0.14	faible	-0.18	faible	-0.10	faible

In summary, the analysis of the annual and seasonal correlation of data from Guinea's eight administrative regions has revealed generally weak relationships. These results demonstrate the absence of significant synergies between these regions, which could pose challenges for investment planning and optimisation